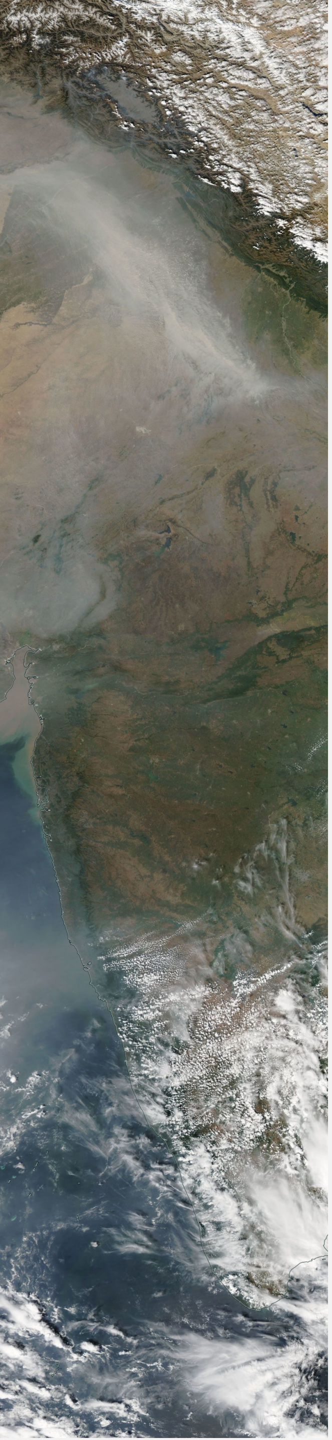

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Converting AOD to $PM_{2.5}$: A Statistical Approach

Pawan Gupta & Ana Prados

Satellite Remote Sensing of Air Quality: Data, Tools, and Applications

Tuesday, May 23, 2017 – Friday, May 26, 2017

Indian Institute of Tropical Meteorology, Pune, India

Objective

- Convert satellite derived aerosol optical depth into surface level $PM_{2.5}$ mass concentration using a statistical approach

Exercise 1: Converting AOD to $PM_{2.5}$

Required Data

- $PM_{2.5}$ mass concentration from ground monitors
- Satellite derived aerosol optical depth
- **Meteorological Fields** – only if working with a multi-variable method

Correlation Between $PM_{2.5}$ & AOD

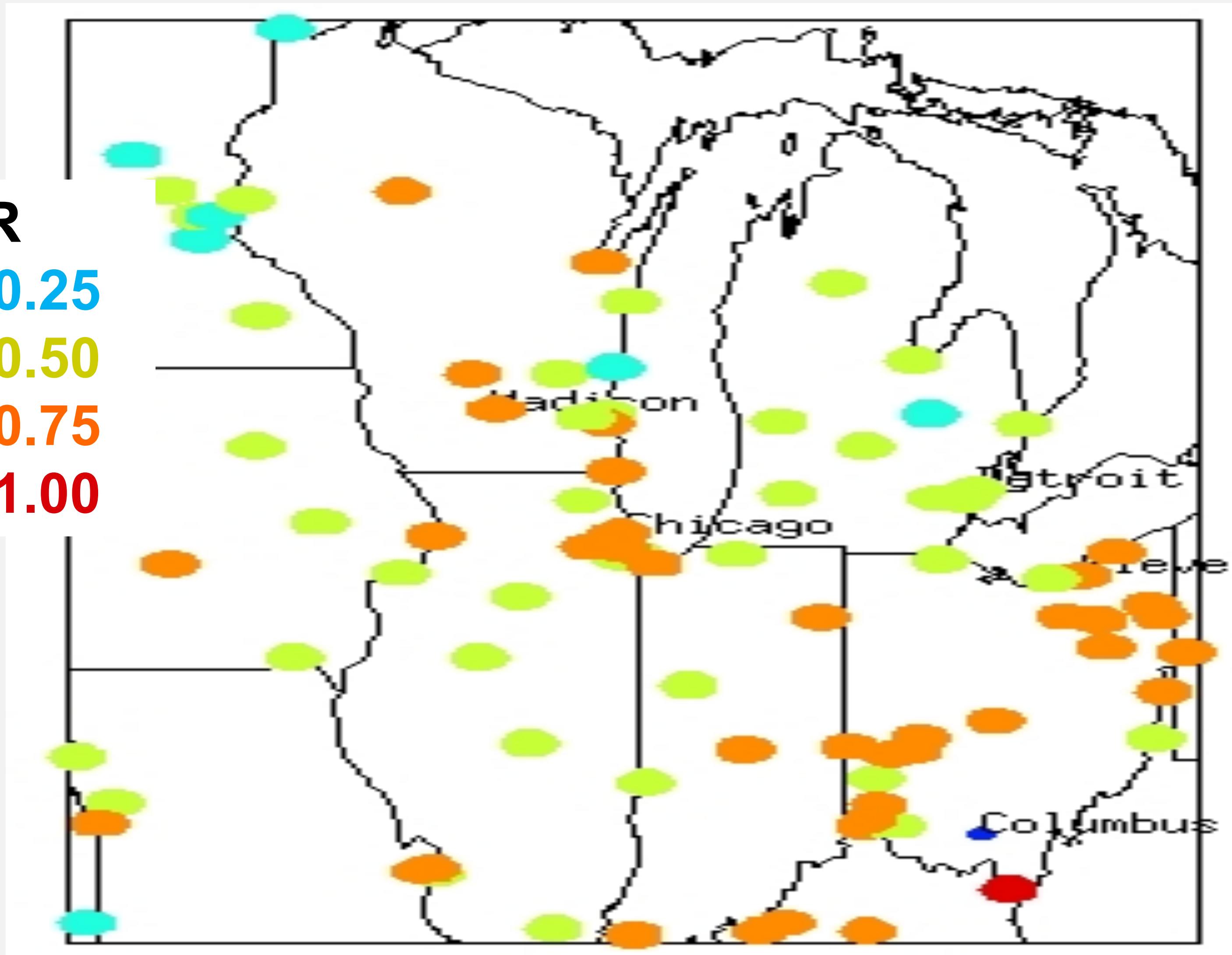
R

0.00-0.25

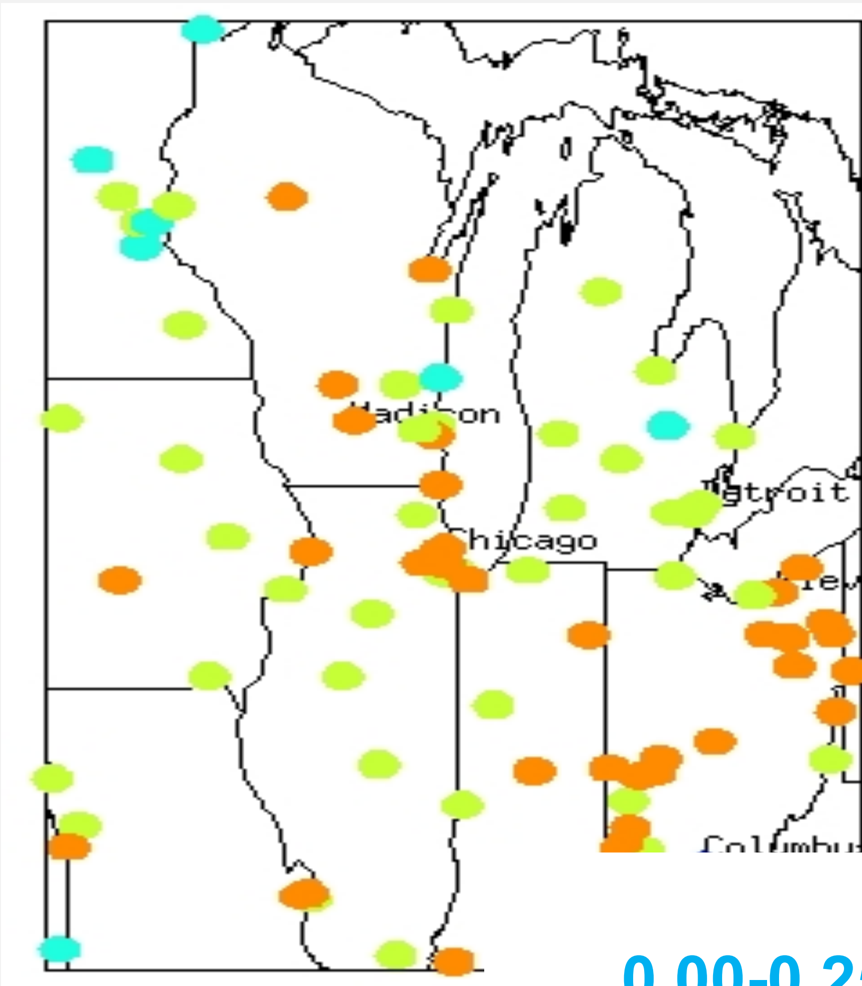
0.25-0.50

0.50-0.75

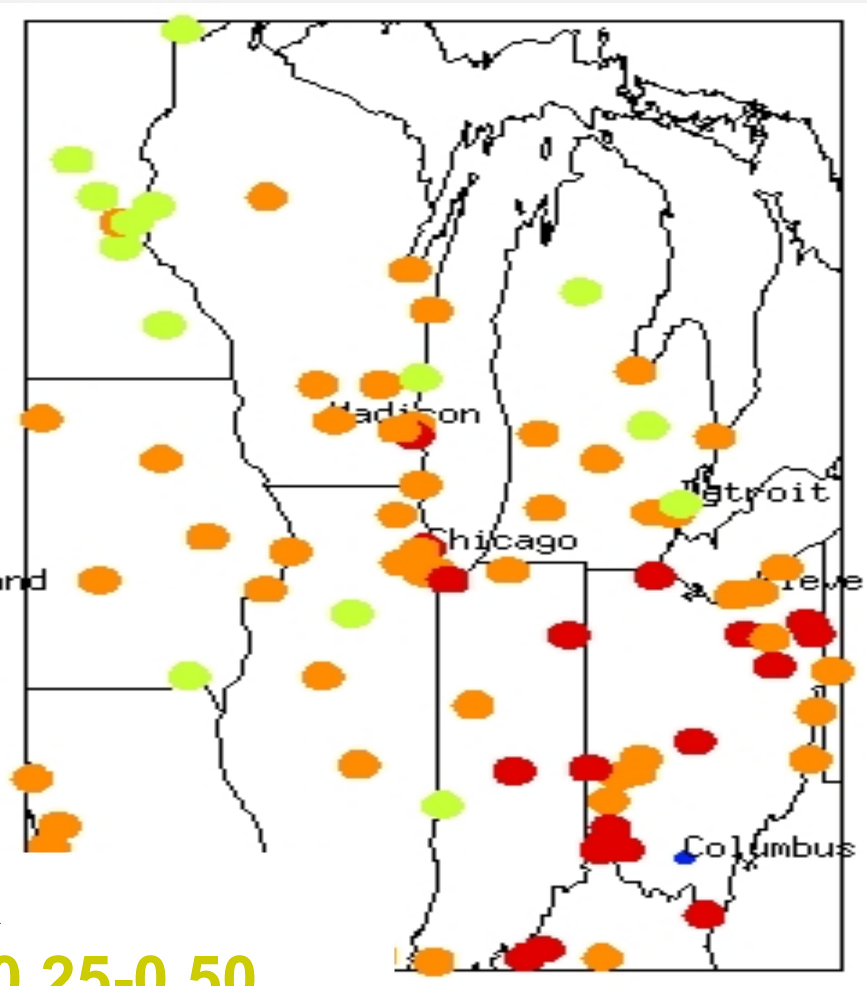
0.75-1.00



Two Variable Method



Multivariable Method



R

0.00-0.25 0.25-0.50

0.50-0.75 0.75-1.00

Converting AOD to $PM_{2.5}$ to AQC

Step 1: Getting Satellite and Surface Data

- Obtain a MODIS AOD data file from the NASA data server for your region, date, and time of interest
  - http://ladsweb.nascom.nasa.gov/
  - from earlier exercise

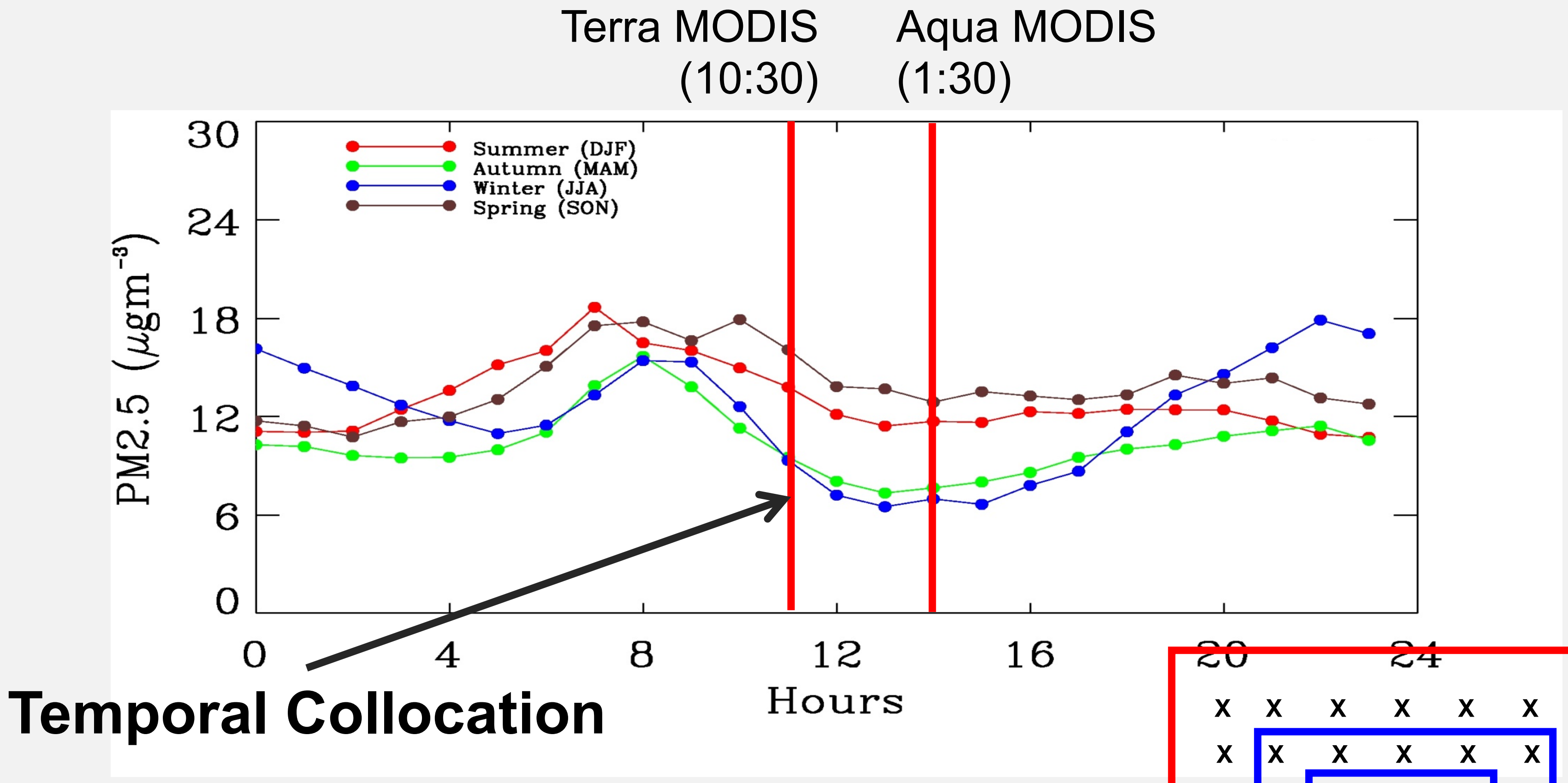
- To get $PM_{2.5}$ for your region:
  - For U.S. Data: http://www.epa.gov/airdata/ad_maps.html
  - Global Air Quality Monitoring System: http://aqicn.org
  - Global Open Data: http://openaq.org
  - Your own data source or measurements

Converting AOD to $PM_{2.5}$ to AQC

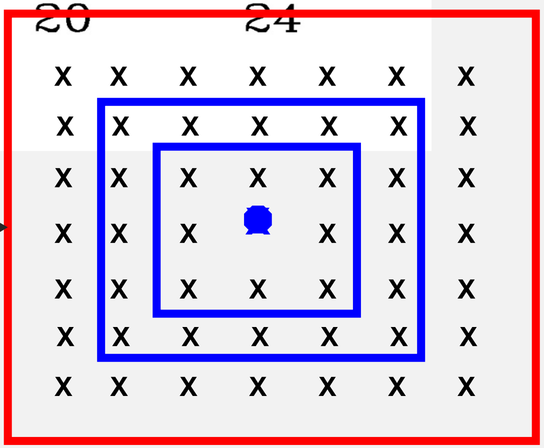
Step 2: Collocating Satellite and Surface Data

- Run IDL, Matlab, HDFLook, Python, etc. code to obtain AOD at the location of the $PM_{2.5}$ ground monitor
  - Python scripts: https://arset.gsfc.nasa.gov/airquality/python-scripts-aerosol-data-sets-merra-modis-and-omi
  - IDL code: http://arset.gsfc.nasa.gov/sites/default/files/airquality/workshops/Santa_Cruz_2013/read_mod04_map_aqc.zip
- Spatial and Temporal Collocation Methods
  - pick the nearest pixel or average over 3x3 or 5x5 pixels
  - pick the closes PM2.5 measurement from ground to satellite overpass time
    - If hourly data is unavailable, then daily mean data can be used as well

Step 2: Continued

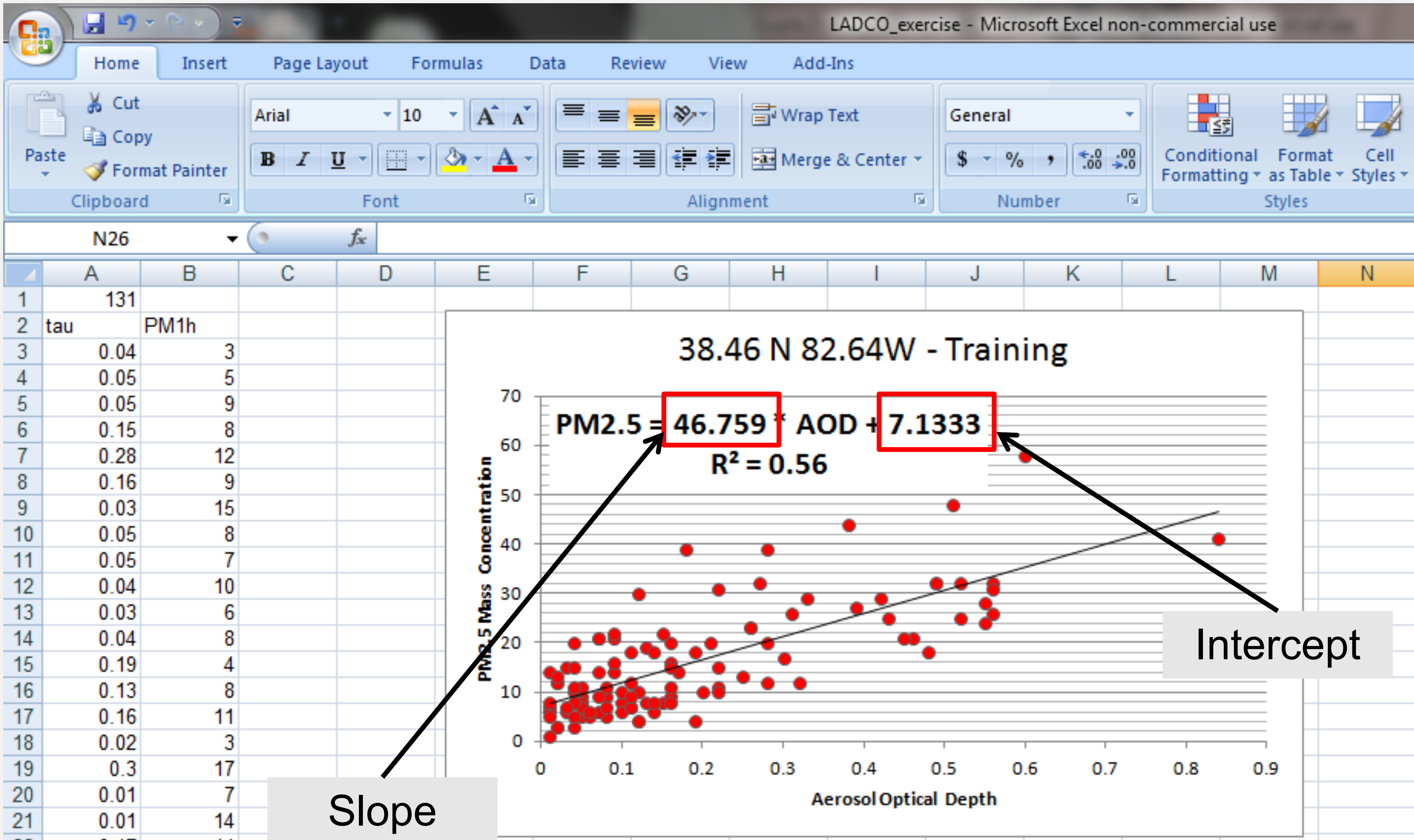


Spatial Collocation



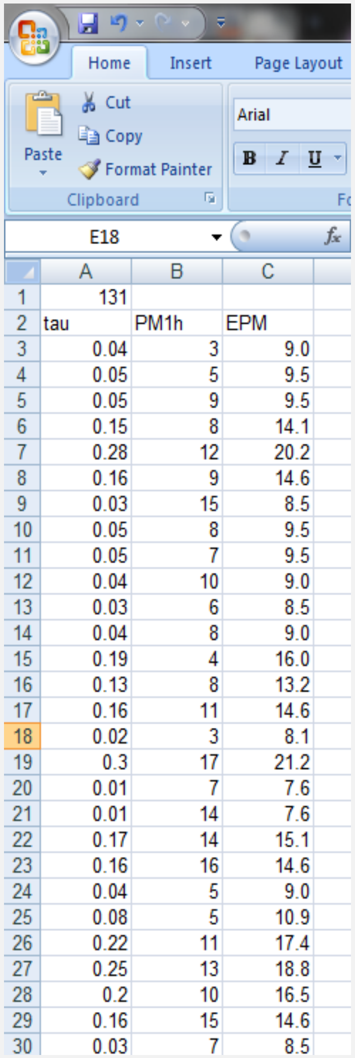
Converting AOD to $PM_{2.5}$ to AQC

Step #3: Developing a Relationship Between AOD & PM2.5



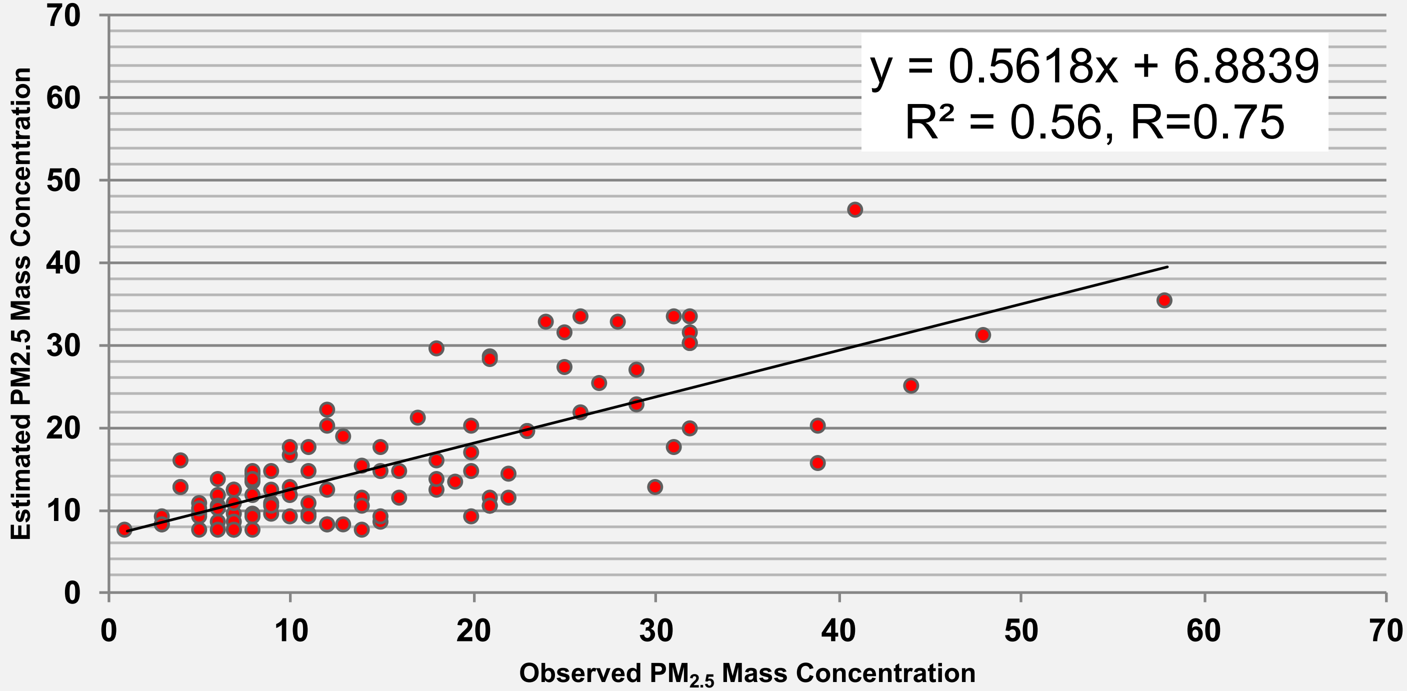
Converting AOD to $PM_{2.5}$ to AQC

Step 4: Estimating $PM_{2.5}$ from Satellite AOD



	A	B	C
1	131		
2	tau	PM1h	EPM
3	0.04	3	9.0
4	0.05	5	9.5
5	0.05	9	9.5
6	0.15	8	14.1
7	0.28	12	20.2
8	0.16	9	14.6
9	0.03	15	8.5
10	0.05	8	9.5
11	0.05	7	9.5
12	0.04	10	9.0
13	0.03	6	8.5
14	0.04	8	9.0
15	0.19	4	16.0
16	0.13	8	13.2
17	0.16	11	14.6
18	0.02	3	8.1
19	0.3	17	21.2
20	0.01	7	7.6
21	0.01	14	7.6
22	0.17	14	15.1
23	0.16	16	14.6
24	0.04	5	9.0
25	0.08	5	10.9
26	0.22	11	17.4
27	0.25	13	18.8
28	0.2	10	16.5
29	0.16	15	14.6
30	0.03	7	8.5

$$PM_{2.5} = AOD*46.7 + 7.13$$



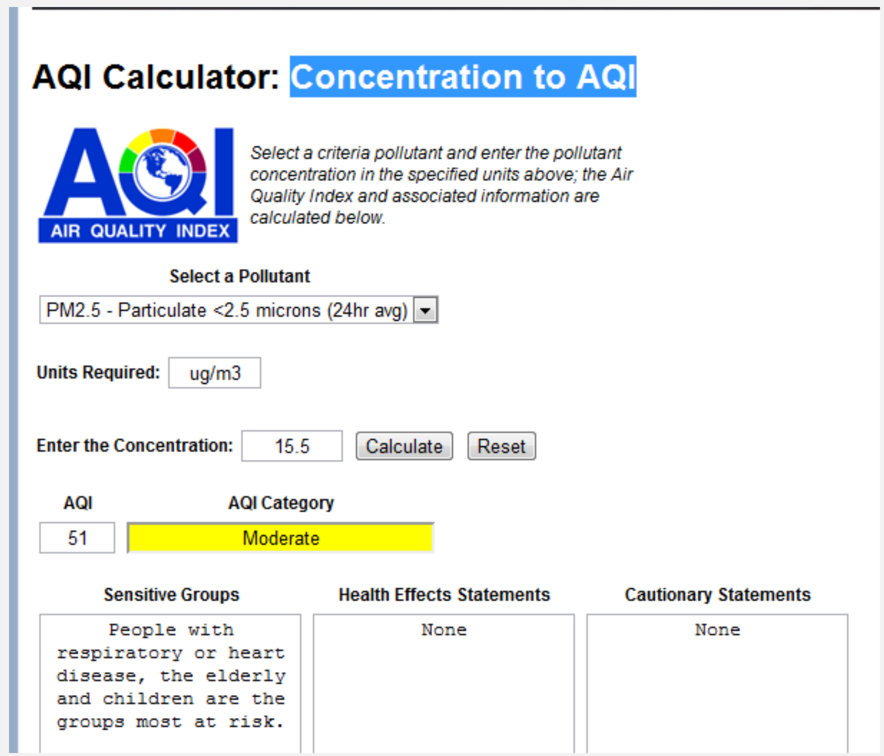
In ideal conditions, two separate datasets should be used to form the relationship and to test or validate the regression equation

Converting AOD to $PM_{2.5}$ to AQC

Step 5: $PM_{2.5}$ to Air Quality

Category	AQI Estimated 24-hour avg. µg/m³
Good (0 - 50)	0 to 15.4
Moderate (51 - 100)	15.5 to 40.4
Unhealthy for Sensitive Groups (101 - 150)	40.5 to 65.4
Unhealthy (151 - 200)	65.5 to 150.4
Very Unhealthy (201 - 300)	150.5 to 250.4
Hazardous (301 - 500)	>250.4

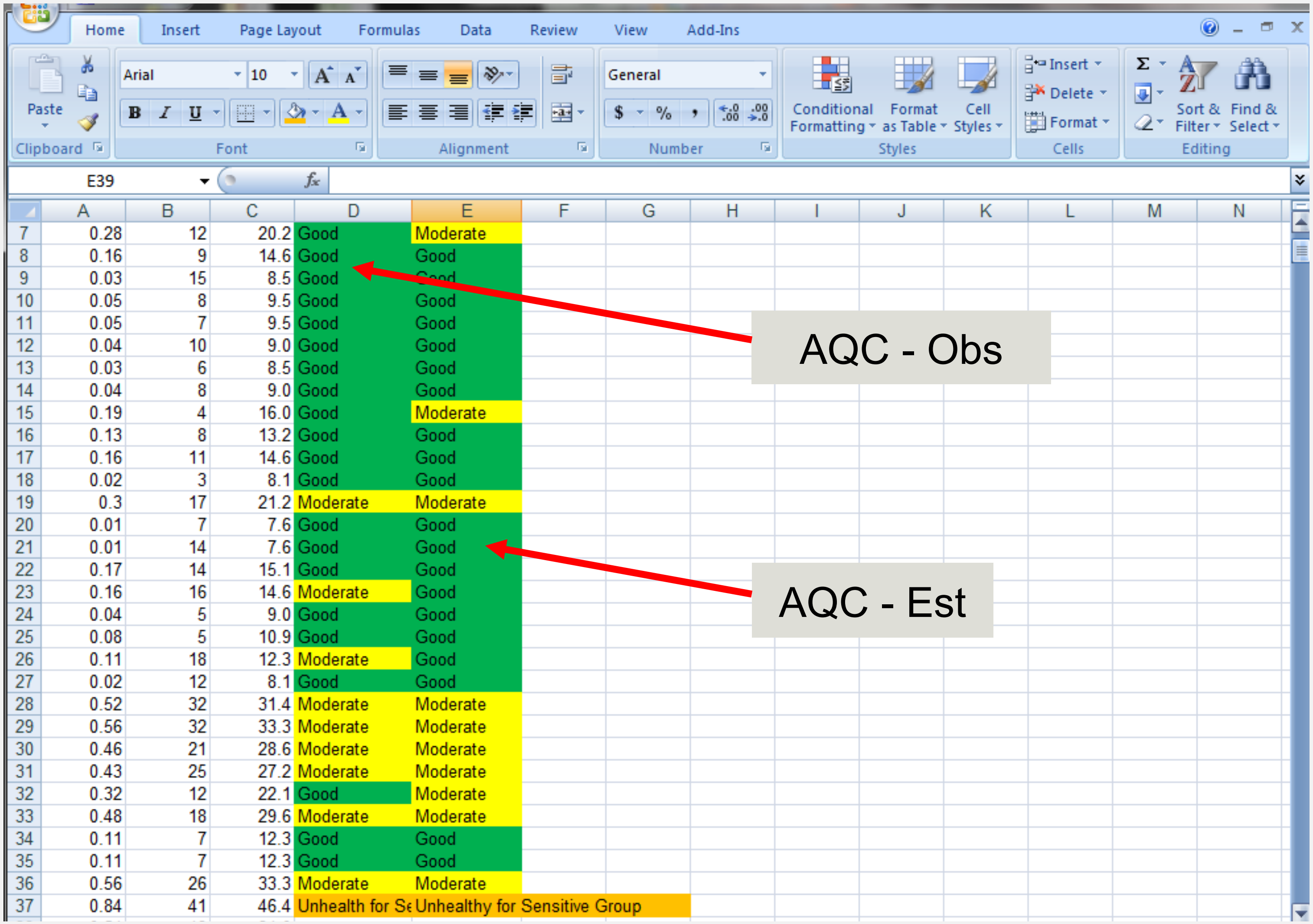
Online Tool



This is based on the U.S. EPA's definition of AQI, which can be different in other countries

Converting AOD to $PM_{2.5}$ to AQC

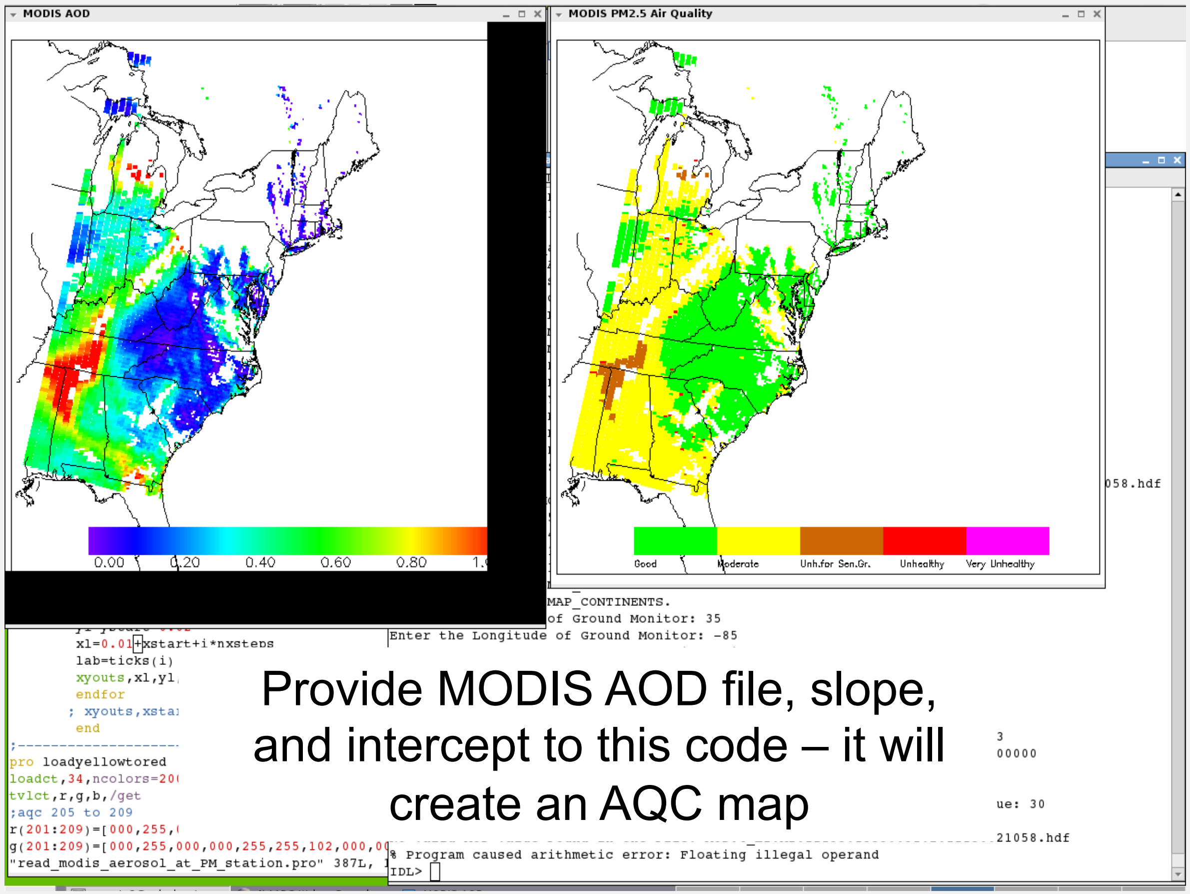
Step 5: $PM_{2.5}$ to Air Quality



	A	B	C	D	E
7	0.28	12	20.2	Good	Moderate
8	0.16	9	14.6	Good	Good
9	0.03	15	8.5	Good	Good
10	0.05	8	9.5	Good	Good
11	0.05	7	9.5	Good	Good
12	0.04	10	9.0	Good	Good
13	0.03	6	8.5	Good	Good
14	0.04	8	9.0	Good	Good
15	0.19	4	16.0	Good	Moderate
16	0.13	8	13.2	Good	Good
17	0.16	11	14.6	Good	Good
18	0.02	3	8.1	Good	Good
19	0.3	17	21.2	Moderate	Moderate
20	0.01	7	7.6	Good	Good
21	0.01	14	7.6	Good	Good
22	0.17	14	15.1	Good	Good
23	0.16	16	14.6	Moderate	Good
24	0.04	5	9.0	Good	Good
25	0.08	5	10.9	Good	Good
26	0.11	18	12.3	Moderate	Good
27	0.02	12	8.1	Good	Good
28	0.52	32	31.4	Moderate	Moderate
29	0.56	32	33.3	Moderate	Moderate
30	0.46	21	28.6	Moderate	Moderate
31	0.43	25	27.2	Moderate	Moderate
32	0.32	12	22.1	Good	Moderate
33	0.48	18	29.6	Moderate	Moderate
34	0.11	7	12.3	Good	Good
35	0.11	7	12.3	Good	Good
36	0.56	26	33.3	Moderate	Moderate
37	0.84	41	46.4	Unhealth for Se	Unhealthy for Sensitive Group

Creating an Air Quality Category Map

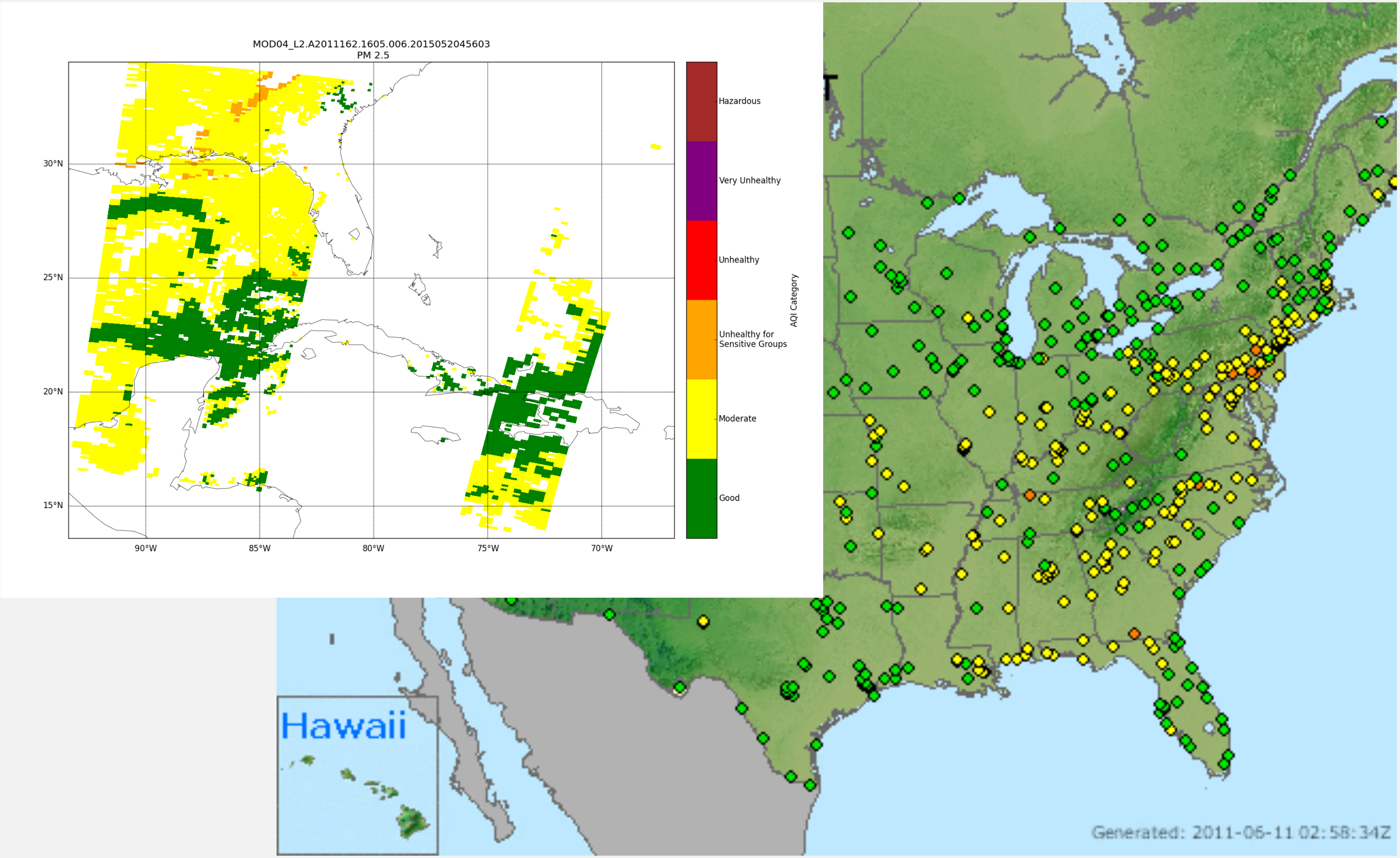
Python/IDL Tool



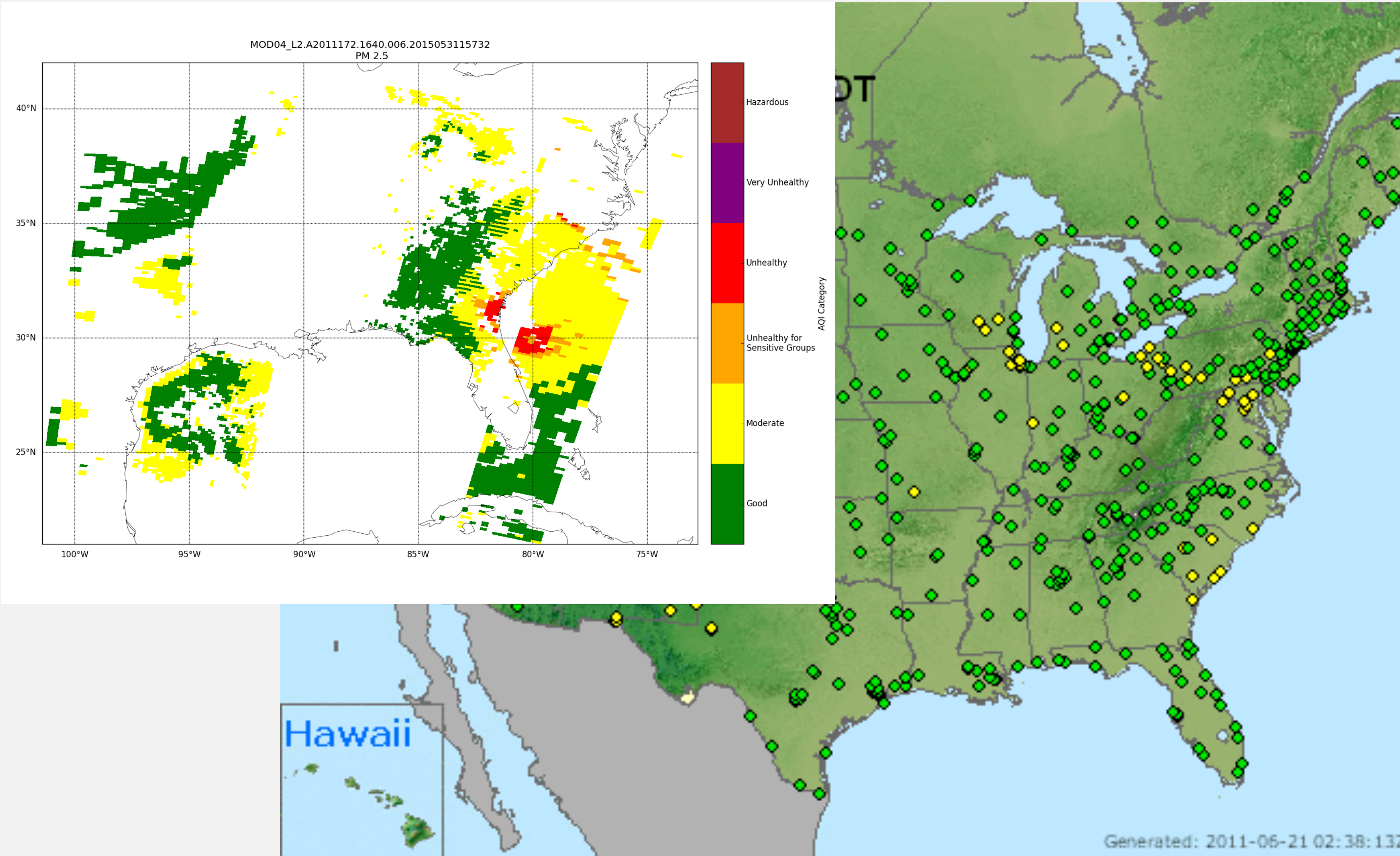
Provide MODIS AOD file, slope, and intercept to this code – it will create an AQC map

http://arset.gsfc.nasa.gov/airquality/python-scripts-aerosol-data-sets-merra-modis-and-omi

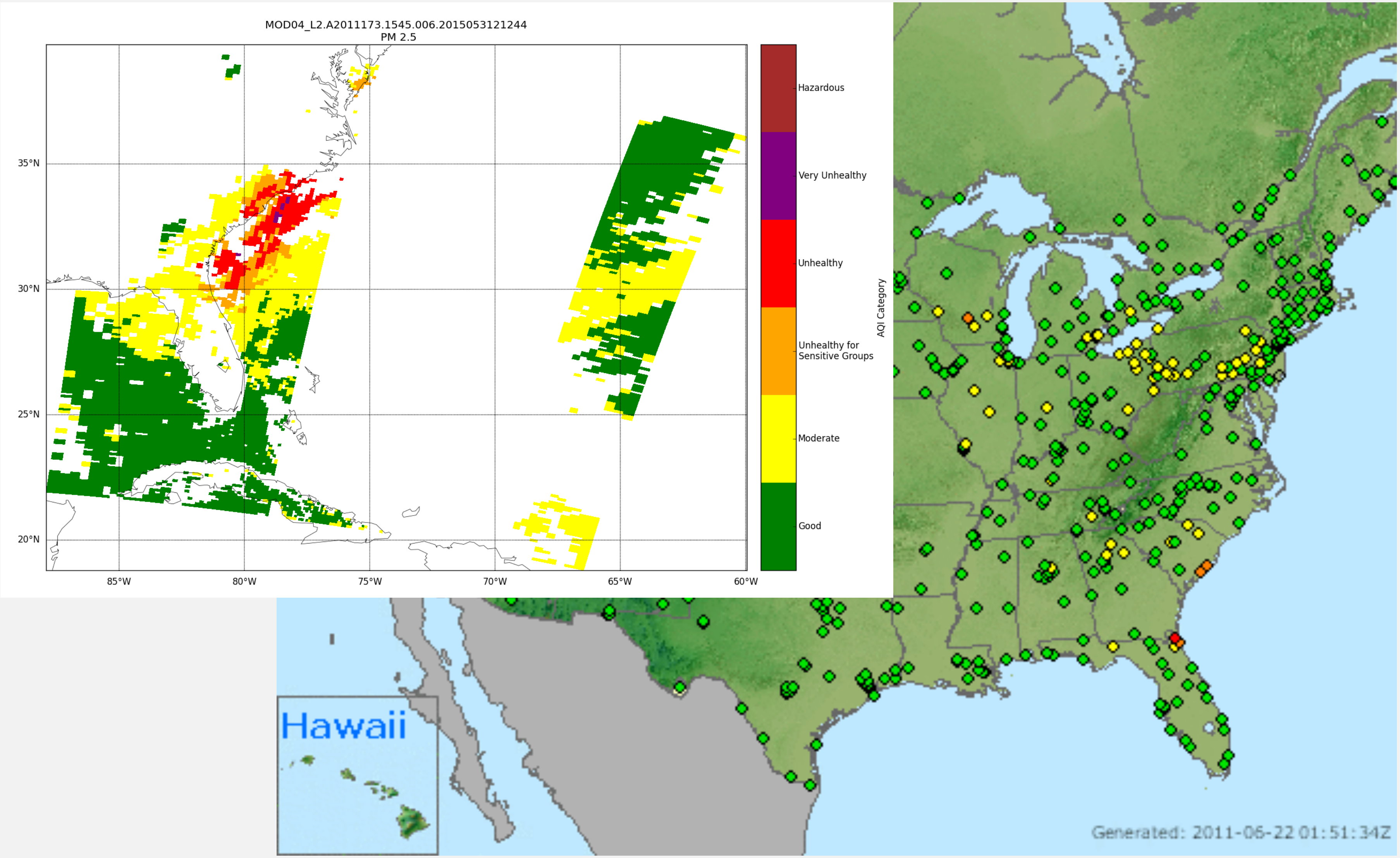
June 10, 2011


MOD04_L2.A2011162.1605.006.2015052045603
PM 2.5
30°N
25°N
20°N
15°N
90°W
85°W
80°W
75°W
70°W
Hazardous
Very Unhealthy
Unhealthy
Unhealthy for Sensitive Groups
Moderate
Good
AQI Category
Hawaii
Generated: 2011-06-11 02:58:34Z

June 20, 2011


MOD04_L2.A2011172.1640.006.2015053115732
PM 2.5
40°N
35°N
30°N
25°N
100°W
95°W
90°W
85°W
80°W
75°W
Hazardous
Very Unhealthy
Unhealthy
Unhealthy for Sensitive Groups
Moderate
Good
AQI Category
Hawaii
Generated: 2011-06-21 02:38:13Z

June 21, 2011



MOD04_L2.A2011173.1545.006.2015053121244
PM 2.5
35°N
30°N
25°N
20°N
85°W
80°W
75°W
70°W
65°W
60°W
Hazardous
Very Unhealthy
Unhealthy
Unhealthy for Sensitive Groups
Moderate
Good
AQI Category
Hawaii
Generated: 2011-06-22 01:51:34Z

Multiple Linear Regression Method

$$\boldsymbol{PM2.5} = \beta_{\boldsymbol{0}} + \alpha * \tau + \sum_{\boldsymbol{n=1}}^{\boldsymbol{m}} (\beta_{\boldsymbol{n}} * \boldsymbol{M_n})$$

Required AOD and meteorological fields and more data processing, more expertise but most of the time produce more accurate $PM_{2.5}$ estimation

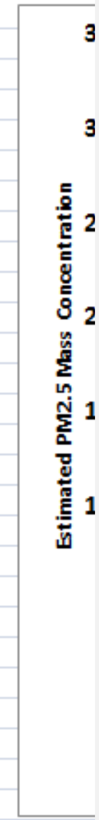
Multiple Linear Regression Model

AOD, $PM_{2.5}$, and Meteorological Data

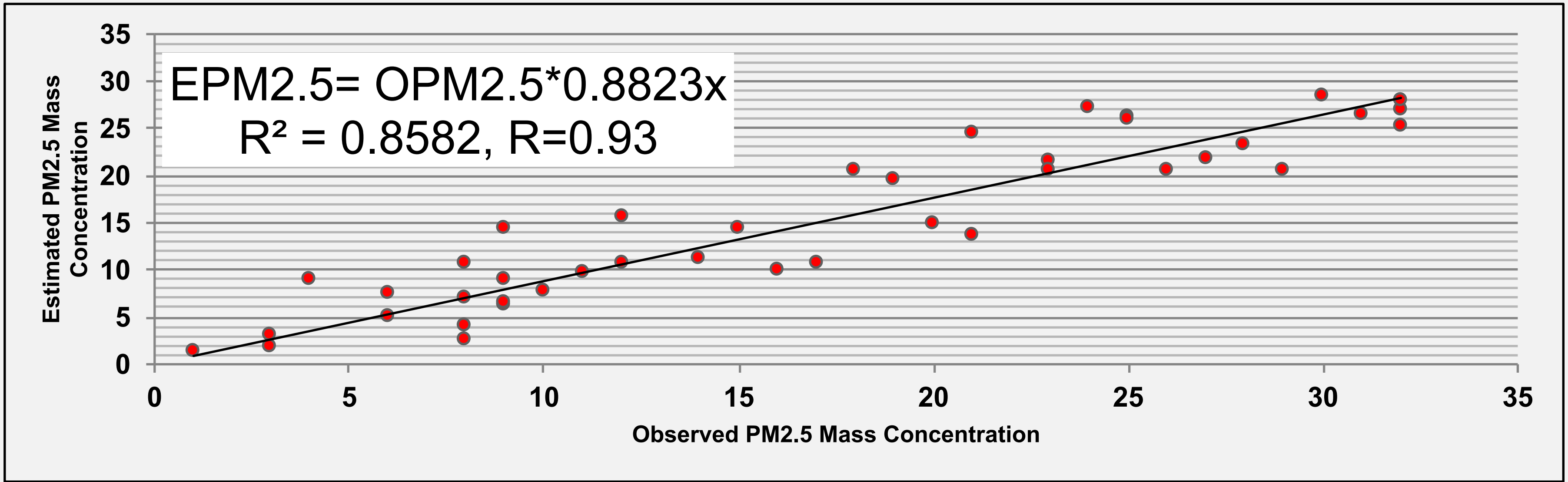
Clipboard | Font | Alignment | Number | Styles

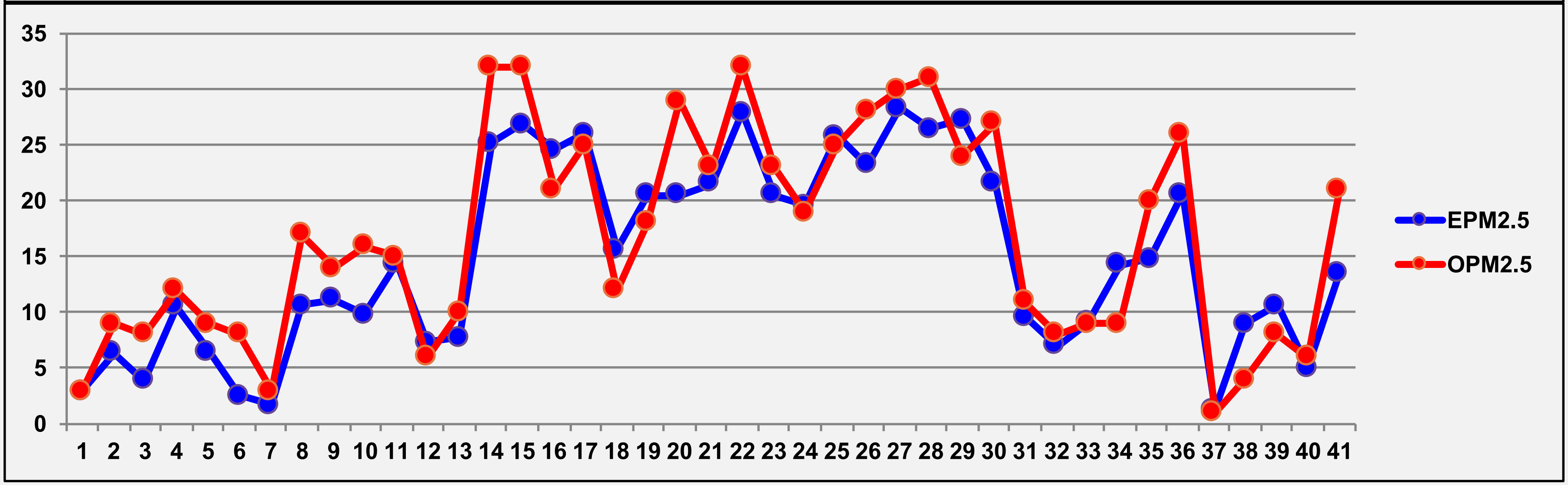
N3 | f_x | =17.02*A3+1.14*D3-0.92*E3+0.44*F3-0.95*G3+1.04*H3-0.04*I3-0.31*J3-0.031*K3-0.0022*L3-177.26

	C	D	E	F	G	H	I	J	K	L	M	N
1	atitude = 38.46, Longitude = -82.64											
2	PM1h	tmp0	tmp1000	tmp700	rh0	rh1000	rh700	ws0	ws925	hpbl		EPM2.5
3	3	277.47	277.4	266.05	71.26	71	70.32	4.14	16.22	63.33		2.995254
4	9	287.25	285.97	270.8	28.95	29.41	39.34	2.76	1.41	623.5		6.35489
5	8	274.13	273.1	260.93	63.01	63.56	17.28	4	8.79	675.67		3.911136
6	12	287.43	286.53	269.72	46.23	46.52	23.82	3.64	9.04	800.67		10.58439
7	9	275.9	275.85	264.3	59.98	60.34	11.2	3.39	5.76	53		6.47774
8	8	283.18	281.67	265.93	35.44	35.57	79.54	0.65	2.47	676.83		2.494904
9	3	286.07	283.98	265.25	36.55	36.66	42.77	4.46	9.49	1325.83		1.748084
10	17	297.03	297.98	275.33	52.06	51.57	81.85	4.04	13.09	925.5		10.67131
11	14	296.88	294.37	274.78	29.43	29.35	27.39	2.18	6.37	1633.33		11.1627
12	16	297.05	295.72	275.03	25.06	25.43	44.91	4.98	16.45	914.83		9.828424
13	15	299.85	297.52	275.25	42.4	42.92	42.66	3.17	6.19	1281.5		14.36151
14	6	289.07	287.65	269.45	57.64	58.14	68.48	4.43	34.55	478.83		7.372424
15	10	295.3	293.57	273.68	42.91	43.34	88.06	3.94	17.43	1226		7.74657
16	32	301.9	299.88	282.63	51.67	51.79	32.02	2.83	9.8	585.17		25.24983
17	32	303.42	300.45	282.27	50.19	50.36	23.46	2.64	6.74	833.5		26.84926
18	21	299.68	297.82	279.97	80.46	80.25	68.37	2.38	6.51	75		24.58039
19	25	304.13	301.87	283.48	64.15	64.42	31.91	3.5	6.1	541.17		26.09083
20	12	295.48	295.2	276.62	64.84	63.68	18.02	4.36	6.28	849.83		15.65489
21	18	300.6	297.15	276.12	45.32	45.23	21.52	1.03	2.05	1799.67		20.49068
22	29	302.4	299.1	279.78	60.49	60.86	47.22	3.41	5.88	1457.67		20.51765
23	23	303.7	300.62	282.55	60.82	60.86	12.18	2.56	6.53	1655.67		21.5245
24	32	307.48	303.73	284.97	63.16	63.1	57.85	1.99	6.4	969.83		27.92127
25	23	306.27	304.75	282.85	59.03	58.51	43.11	2.42	6.73	880.5		20.54857
26	19	307.38	304.78	283.63	51.07	51.09	34.56	4.67	7.7	777.83		19.60247
27	25	306.15	303.15	283.25	60.33	60.41	56.95	4.62	6.13	953.83		25.84764
28	28	304.92	303.35	283.4	63.96	63.78	81.48	2.4	6.46	1561.83		23.25351
29	30	302.98	302.9	281.58	59.39	59.84	94.25	3.08	6.66	1391.33		28.37551
30	31	301.35	300.05	282.43	60.76	60.4	33.71	2.94	7.29	89.33		26.44508
31	24	305.43	302.2	280.67	55.96	56.51	23.92	2.29	3.24	1058.83		27.27383
32	27	301.4	300.43	281.02	56.77	57.2	33.22	4.01	10.04	537.6		21.71764



Multiple Linear Regression Method Results





!! CAUTION !!

- Regression analysis provides the first approximation of surface PM2.5 mass concentration and air quality
- Its accuracy depends on training data and varies in space and time
- Careful data quality control, testing, and validation should be performed before using this method for quantitative analysis
- Works best when the boundary layer is well mixed, there is no significant aerosol aloft, and in small particle dominated regions